5.16.20 MASS PER CUBIC METER (FOOT), YIELD CEMENT FACTOR AND AIR CONTENT (GRAVIMETRIC) OF FRESH CONCRETE (Kansas Test Method (KT-20)

a. SCOPE

This method of test covers the procedure for determining the mass per cubic meter (foot) of freshly mixed concrete and gives formulas for calculating the following values: Yield, Cement Factor, Relative Yield, Actual Cement Factor and Air Content. KT-20 reflects testing procedures found in AASHTO T 121.

NOTE: This method of calculating air content is of value when equipment is not available for making the test in accordance with the preferred Kansas Test Methods such as KT-18 and KT-19. This gravimetric method is not applicable for concrete or mortar made with highly porous aggregates.

b. REFERENCED DOCUMENTS

b.1. KT-15; Bulk Specific Gravity and Unit Weight of Compacted Bituminous Mixtures

b.2. KT-17; Sampling Fresh Concrete

b.3. KT-18; Air Content of Freshly Mixed Concrete By the Pressure Method

b.4. KT-19; Air Content of Fresh Concrete By the Volumetric Method

b.5. AASHTO M 231; Weighing Devices Used in the Testing of Materials

b.6. AASHTO T 121; Weight per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete

c. APPARATUS

c.1. Balance having a capacity of 50 kg and conforming to AASHTO M 231, Class G100.

c.2. Tamping rod shall be a straight steel rod 16 mm (5/8 in) in diameter, approximately 600 mm (24 in) long and having the tamping end rounded to a hemispherical tip the diameter of which is 16 mm ($^5/_8$ in).

c.3. Measure; A cylindrical container made of steel or other suitable material[a]. It shall be watertight and sufficiently rigid to retain its form and calibrated volume under rough usage. Measures that are machined to accurate dimensions on the inside and provided with handles are preferred. The minimum capacity of the measure shall conform to the requirements of Table 1. All measures, except for measuring bowls of air meters which are also used for KT-20 tests, shall conform to the requirements of KT-5. When measuring bowls of air meters are used, they shall conform to the requirements of KT-18. The top rim of the air meter bowls shall be smooth and plane within 0.25 mm (0.01 in).[b]

NOTE a: The metal or other suitable material should not be readily subject to attack by cement paste. However, reactive materials such as aluminum alloys may be used in instances where as a consequence of an initial reaction, a surface film is rapidly formed which protects the metal against further corrosion.

NOTE b: The top rim is satisfactorily plane if a 0.25 mm (0.01 in) feeler gage cannot be inserted between the rim and a piece of 6 mm (1/4 in) or thicker plate glass laid over the top of the measure.

Table 1 Minimum Capacity of Measures[e]

Maximum Nominal Size of Coarse Aggregate[c]		Capacity of Measure, min[d]	
mm	in	m^3	ft^3
25.0	1	0.006	0.2
37.5	1½	0.011	0.4
50	2	0.014	0.5
75	3	0.028	1.0
114	4½	0.071	2.5
152	6	0.099	3.5

NOTE c: Aggregate of a given maximum nominal size may contain up to 10% of particles retained on the sieve referred to.

NOTE d: To provide for wear, measures may be up to 5% smaller than indicated in this table.

NOTE e: For maximum nominal aggregate sizes 25 mm (1 in) or less, the pressure meter bowl may be used.

c.4.[1] A rigid, flat glass or heavy plastic cover plate at least 13 mm (½ in) thick and at least 50 mm (2 in) larger then the diameter of the measure for accurately striking off and leveling the surface of the concrete. The edges of the plate shall be straight and smooth with a tolerance of 1.6 mm (1/16 in).

c.5. Hand Scoop.

1 AASHTO T 121 allows the use of a metal plate.

c.6. Trowel.

c.7. Mallet with rubber or rawhide head having a mass of 570 ± 227 g (1.25 ± 0.50 lb), for use with measures 0.014 m^3 (0.5 ft^3) or smaller. A mallet having a mass of 1020 ± 227 g (2.25 ± 0.50 lb) for larger measures.

c.8. Internal vibrator: Internal vibrators may have rigid or flexible shafts, preferably powered by an electric motor. The diameter of the vibrating element shall be not less than 19 mm (0.75 in) or more then 38 mm (1.50 in) and the length of the shaft should be 600 mm (24 in) or more. The frequency of vibration shall be 117 Hz (7,000 vibrations per minute) or greater. A tachometer should be used to check the frequency of vibration.

d. CALIBRATION OF MEASURE, AND CALIBRATION FACTOR

d.1. Determine the mass of the empty measure (coated with grease on the top rim if necessary) and cover plate to the nearest 20 g (0.05 lb) and record.

d.2. Fill the measure with water, using the cover plate to insure that it is exactly full. Wipe excess water from sides and bottom of the measure with an absorbent cloth.

d.3. Weigh and record the mass of the measure, water, and cover plate.

d.4. Measure and record the temperature of the water and determine the density as found in KT-15, interpolating if needed.

d.5. Calculations:

$$V = \frac{B-C}{D}$$

Where:
V = Volume of the measure, m^3 (ft^3).
B = Mass of the measure filled with water plus cover plate, kg (lb).
C = Mass of the measure and cover plate, kg (lb).
D = Density of water (See KT-15).

$$F = \frac{D}{B-C} = \frac{1}{V}$$

Where: F = Calibration Factor.

e. TEST PROCEDURE

e.1. Obtain a sample of fresh concrete in accordance with KT-17.

e.2. Weigh the measure and record its mass.

e.3. Methods of Consolidation: Concrete at different slump levels require different methods of consolidation to prepare satisfactory test specimens. The methods listed below should be used as a guide in determining the type of consolidation to use:

Slump of Concrete	Type of Consolidation
More than 75 mm (3 in)	Rodding
25 to 75 mm (1 to 3 in)	Rodding or Vibration
less than 25 mm (1 in)	Vibration

e.4. Rodding Procedure.

e.4.a. Place concrete in the measure in three equal layers.

e.4.b. Rod each layer 25 times when 0.014 m^3 (0.5 ft^3) or smaller measures are used and 50 times when the 0.028 m^3 (1ft^3) measure is used. When rodding the first layer, avoid striking the bottom of the container. When rodding successive layers, use only enough force to penetrate the surface of the underlying layer.

e.4.c. After each layer is rodded tap the exterior surface of the base with the mallet 10 to 15 times to eliminate the voids left by rodding.

e.4.d. After consolidation, strike-off the top surface of the concrete and finish it smoothly with the flat strike-off plate using great care to leave the measure just level full. The strike-off is best accomplished by pressing the strike-off plate on the top surface of the measure to cover about two-thirds of the surface and withdrawing the plate with a sawing motion to finish only the area originally covered. Then place the plate on the top of the measure to cover the original two-thirds of the surface and advance it with a vertical pressure and a sawing motion to cover the whole surface of the measure. Several final strokes with the inclined edge of the plate will produce a smooth finished surface.

e.4.e. With the cover plate in place, clean all excess concrete from the exterior of the filled measure and the cover plate. Weigh the measure, concrete and cover plate to the nearest 50 g (0.1 lb) and record the mass.

e.5. Vibration Procedure.

e.5.a. Fill the measure approximately 1/2 full of concrete. Place all the concrete required for the layer in the measure before starting vibration.

e.5.b. Consolidate the layer by three insertions of the vibrator evenly distributed over the surface. The duration of vibration will depend on the effectiveness of the vibrator and the consistency of the concrete, but usually sufficient vibration has been applied when the surface of the concrete becomes relatively smooth in appearance.

e.5.c. Fill the measure to an elevation somewhat above the top rim and vibrate this second layer. A small quantity of concrete may be added to correct a deficiency. If the measure contains a great excess of concrete at completion of consolidation, remove most of the excess concrete with a trowel or scoop immediately before the measure is struck-off.

e.5.d. Strike-off the surface as in **e.4.d.**

e.5.e. Proceed as in **e.4.e.**

e.5.f. Special Precautions:

e.5.f.1. Do not allow the vibrator to rest on the bottom or touch the sides of the measure when vibrating the bottom layer.

e.5.f.2. When vibrating the top layer, penetrate the layer and approximately the top 25 mm (1 in) of the bottom layer.

e.5.f.3. Withdraw the vibrator in such a manner that no air pockets are left in the concrete.

f. CALCULATIONS

f.1. Mass per cubic meter (foot) of fresh concrete.

$$W = F(D-C)$$

Where: W = Mass of concrete, kg/m^3 (lb/ft^3).
D = Mass of measure filled with concrete plus cover plate, kg (lb).
C = Mass of measure and cover plate, kg (lb).
F = Calibration Factor.

f.2. Volume of Concrete Produced per Batch:

$$S = \frac{W_c + W_{fa} + W_{ca} + W_w + W_o}{W}$$

Where: S = Volume of concrete produced per batch, m^3 (ft^3).
W_c = Total mass of cement in batch, kg (lb).
W_{fa} = Total wet mass of fine aggregate in batch, kg (lb).

W_{ca} = Total mass of coarse aggregate in batch, kg (lb).
W_w= Total mass of mixing water added to batch, kg (lb).
W_o= Total mass of any other solid or liquid material used, kg (lb).

f.3. Relative Yield: Relative yield is the ratio of actual volume of concrete obtained to the volume as designed for the batch and shall be calculated as follows:

$$RY = \frac{S}{V_d} \quad \text{(SI)}$$

$$RY = \frac{S}{27(V_d)} \quad \text{(ENGLISH)}$$

Where: RY = Relative Yield[e].
V_d = Volume of concrete which the batch was designed to produce, m^3 (yd^3).

NOTE e: A value for RY greater than 1.00 indicates that an excess volume of concrete is being produced, whereas, a value less than 1.00 indicates the batch to be "short" of its designed volume.

f.4. Yield Cement Factor: calculate as follows:

$$YCF = \frac{\text{Design } CF(W)}{TW}$$

Where: YCF = The cement factor for the concrete being produced as determined from the mass of the concrete.
TW = Theo. Mass, kg/m^3 (lb/ft^3) at design air content.
Design CF = kg of cement/m^3 (lb of cement/yd^3) of concrete.
W = Mass of concrete, kg/m^3 (lb/ft^3).

f.5. Air Content: calculate as follows:

$$A = \frac{100(T-W)}{T}$$

Where: A = Air content in the concrete.
T = Theoretical mass of the concrete, kg/m^3 (lb/ft^3), air-free basis[f].
W = Mass of concrete, kg/m^3 (lb/ft^3).

NOTE f: When the same materials and proportions are used to prepare different batches of concrete, it is assumed that the theoretical, air-free, mass per cubic meter (foot) of the concrete is constant for all batches. It is calculated from the formula:

$$T = \frac{W_1}{V}$$

Where: $W_1 = W_c + W_{fa} + W_{ca} + W_w + W_o$
V = Total absolute volume of the component ingredients in the batch, m^3 (ft^3).

The absolute volume of each ingredient is calculated in accordance with subsection **5.17.01.** For the aggregate components, the bulk specific gravity and mass should be based on the saturated, surface-dry condition.

f.6. Actual Cement Factor: Cement factor based on theoretical m^3 (yd^3) of concrete required and actual quantity of cement used is calculated as follows:

$$ACF = \frac{A}{B}$$

Where: A = Actual cement used, kg (lb).
B = Theoretical volume of concrete, m^3 (yd^3).